1. PUMP TYPES

There are two principal categories of pumps:-

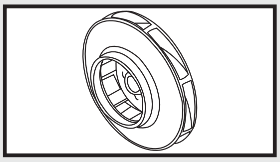
Positive Displacement use the principal fluid displacement by a mechanical device and have the characteristics of when priming at a constant speed they pump fluid at a fixed flow irrespective of system pressure. There are two main types, reciprocating and rotary, the most common being the rotary peripheral type as used for small domestic pumps, though they come in many configurations.

Rotodynamic Pumps depend upon the rotation of a rotor to provide the pumping force and have the characteristics that at a given speed flow varies with pressure. They are further classified according to the type of rotor into radial flow, mixed flow and axial flow types. In radial flow pumps fluid moves through the rotor (or impeller) in a radial direction and pressure is developed by centrifugal force.

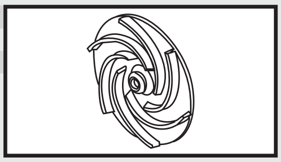
In axial flow pumps the fluid is pumped through the rotor (or propeller) in a direction axial to the motor shaft and pressure is developed by the lifting action of the propeller. Mixed flow pumps have impellers that are a mixture of both types.

The most common rotodynamic pump is the centrifugal type, which are mechanically simple, efficient and economical. Centrifugal pumps also have different types categorised by the impeller design as follows:-

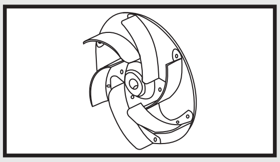
Closed Impeller
The impeller vanes are enclosed between two discs. This is the most efficient design though is only suitable for clear water as the vanes tend to clog when pumping suspended solids.



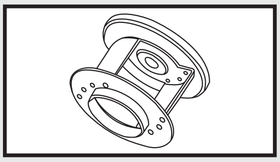
Open Impeller
The vanes are open on one side which improves silt handling capacity but reduces efficiency.



Vortex Impeller
Pumps by creating a vortex in the pump chamber so providing a freer flow passage giving improved silt and solid handling capacity.



Single and Double Channel Impeller
Designed with large flow passages within the impeller for the pumping of fluids with large size solid content.



Cutter & Grinder Impellers
Specialised designs for macerating string materials and small solids before being passed as sludge through the pumps.

When choosing a pump it is most important to select the correct impeller type and impeller materials to avoid operational problems. Generally if water is clean and thin with no suspended solids a closed impeller or peripheral pump should be used. For silted or polluted water an appropriate impeller type should be selected, details of pumps' capacity and applications being given in the product data.

2. PUMP SELECTION

There are three principal performance parameters relating to pump selection:-

- Flow (or Capacity)
- Total Delivery Head
- Suction Lift

2.1 Capacity

Required capacity, measured in flow per unit time is determined by one of two factors:-

- If there is storage capacity it is related to total daily demand. Daily demand must first be estimated and then the hourly requirement calculated by dividing the daily demand by the number of hours the pump is required to work.
- If there is direct supply pump capacity should be related to peak hourly demand. This would be appropriate in irrigation or pressure systems.

Capacity is measured in various units including gallons per hour (gph), gallons per minute (gpm), litres per minute (l/min) and cubic metres (1000 litres) per hour (m^3/hr). All Davis & Shirtliff products are rated in cubic metres per hour (m^3/h), conversion factors being given in Section C.

2.2 Total Head

There are three principal components to total head of importance when specifying a pump: static head, dynamic head (friction loss) and pressure head.

Total Head = Static Head + Dynamic Head + Pressure Head

Static Head (H)

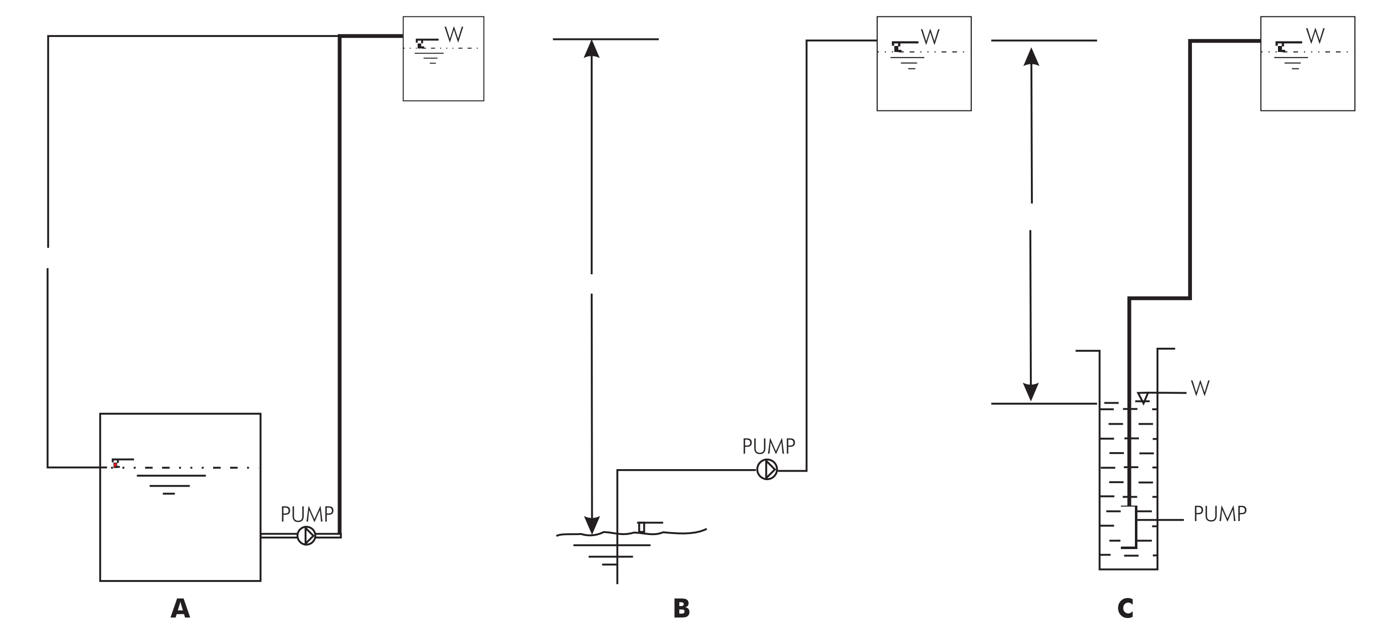


DIAGRAM 1 - Static Head Conditions

Static head is the vertical linear distance between the level of the water being pumped and either the delivery outlet or the reservoir water level, whichever is higher (see A&B). Of great importance to note is that it is not necessarily the distance between the pump itself and the delivery point. This has particular reference to submersible pumps where the level the pump is set in the water does not determine static head. It is determined by the pumping water level (see C). In summary the static head may be considered as the vertical height difference between the water level at the source and the level at the highest point of delivery.

2.3 Dynamic Head

The only important component of dynamic head is pipe friction, this being determined by water velocity in the delivery pipe. The higher the velocity the higher the friction loss and it is important to match the pump to the pipeline. Friction loss values for GI and PVC pipes are given in table 1. Some important points to note when matching pumps and pipelines are:-

- The smoother the pipe's internal surface, the less the friction loss experienced.
- The larger the pipe diameter for a given flow, the less the frictional loss experienced.
- Friction losses are considerably lower in PVC pipes than GI ones. For long pipelines the use of PVC will therefore reduce pump size and energy consumed.
- For long pipe lines the piping cost can be considerably more expensive than the pumping installation and a pipe size smaller matched to a pump size larger can reduce the investment cost. Running costs will be higher though.
- Total head reduces up the pipeline and lighter duty pipes can be used towards the system's delivery point.

Total friction loss for a pipeline, $H_f = (F x L)/100$

Where:-

F = Friction loss given for a particular flow in a specified pipe size (m per 100m pipe length).
L= Pipe length (m)

Pipe friction is not linear and increases logarithmically as velocity (or flow) increases. A typical friction loss curve is given below.

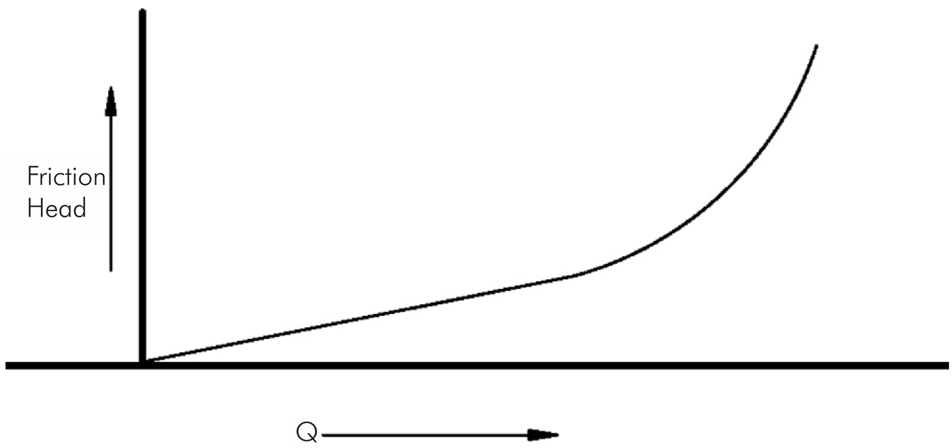


DIAGRAM 2 - Typical Friction Head Loss Curve

This diagram can be plotted using friction loss values given for a particular pipe specification at different flow rates.

2.4 Pressure Head

When delivering to an open outlet pressure at the delivery point is zero and so in most water supply installations this is not a factor in total head calculations. However, when pressure delivery is required e.g. for fire installations or irrigation nozzles the required pressure at the nozzle must be included when calculating total head.

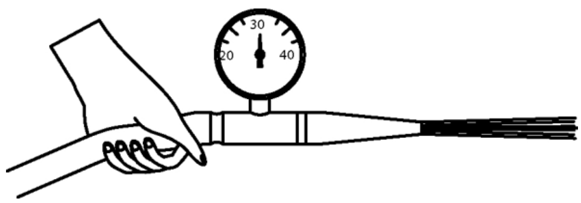


DIAGRAM 3 - Pressure Head Condition

2.5. System Head Curves

In order to find the total head required on a pump, static head plus dynamic head plus friction head must be added. This can be done graphically as follows:

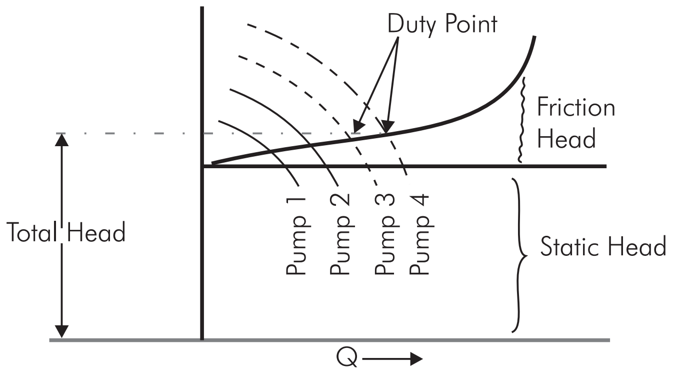


DIAGRAM 4 - System Head Curve

From the above graph pump 3 or pump 4 can be selected, depending upon required pump capacity.

2.6. Suction Lift

Centrifugal pumps have the capability of creating a vacuum in a suction pipe which enables them to suck water from below their setting level. The maximum theoretical suction lift is 1 atmosphere (approx 10m), though the maximum practical lift is well below this.

Maximum suction lift is determined by the formula:-

$H_{max} = A - NPSH - H_f - H_v - H_s$

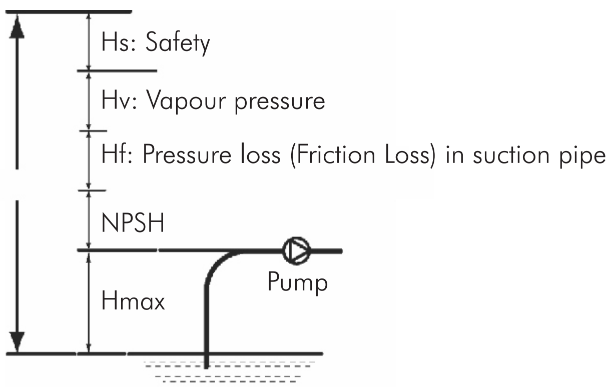


DIAGRAM 5 - Suction Lift Conditions

Considerations relating to the various parameters are as follows:-

A - *Atmospheric pressure. At sea level it is 10.3m reducing by approximate 3% per 300m rise in elevation above sea level. Suction lift is therefore reduced at higher altitudes.*

NPSH - *The suction characteristic of the pump which is shown on the pump manufacturer's curve.*

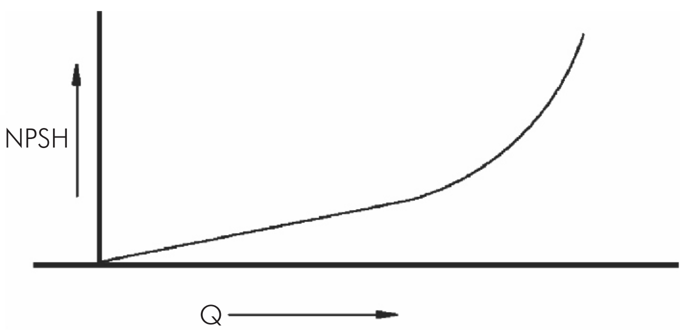


DIAGRAM 6 - Typical NPSH Curve

The higher the flow the higher the NPSH and therefore the lower the available suction lift.

H_f - Friction loss in the suction pipe. This is calculated in a similar way to friction loss under section 1.5.2. The value increases with increasing flow thereby reducing the available suction lift.

H_v - The water vapour pressure. This is an important factor for liquids above 30°C, though is not important at normal ambient temperatures.

Vapour pressure values are as follows:-

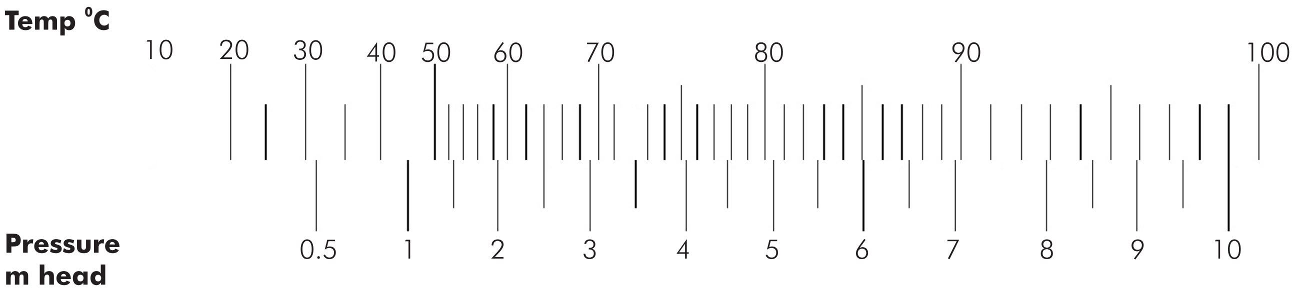


DIAGRAM 7 - Vapour Pressure Values

H_S - A safety margin, usually 1 m being acceptable.

Some general points about suction performance are as follows:-

- It is good practice to keep suction lift as low as possible and suction pipes as short as is practical.
- Suction pipes must be totally airtight. If there are any leaks the pump will be unable to create the vacuum condition for suction to occur.
- Suction pipes must be straight and laid to rise continuously to the pump. If there are any leaks in the pipe air pockets will form and the system will become air locked.
- Suction pipes must be generously sized, one size larger than the delivery pipe being standard practice. Also all suctions should be fitted with foot valves.
- Where the distance from the pump mounting point to the water level is greater than the available suction lift either a submersible or a jet pump should be used.

3. CENTRIFUGAL PUMP PERFORMANCE

3.1 Performance Parameters

When specifying centrifugal pumps it is important to understand the various parameters that effect pump performance and their relationship with one another.

Typically a pump curve will provide the following information.

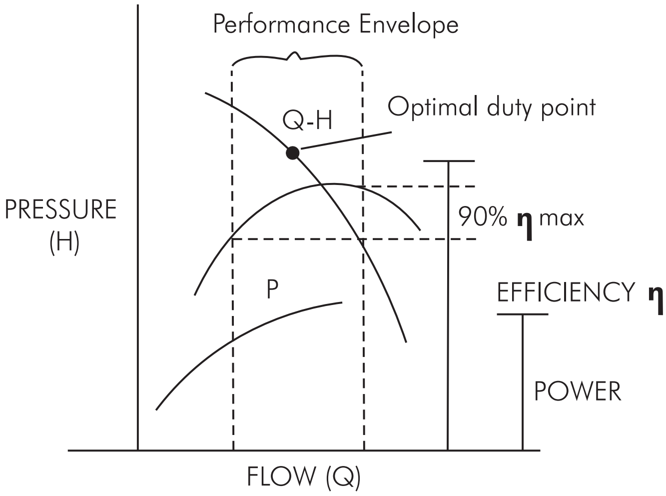


DIAGRAM 8 - Typical Centrifugal Pump Performance Curve

Three plots are given against flow - Pressure (or Q-H curve), Efficiency (η) and Power absorbed.

Pressure: Otherwise known as the pump performance or Q - H curve and plots the pressure/flow profile of the pump.

- At zero flow the pump will provide its maximum pressure (closed head pressure).
- At zero head the pump will provide its maximum flow.

Efficiency (η): The efficiency curve is the plot of overall efficiency against flow or the ratio of power applied to the hydraulic power output. Points to note are:-

- The pump's optimal duty point is that at which peak efficiency occurs and is usually around the mid point of the curve. The optimal performance envelop is the flow range which is greater than 90% of the pump's maximum efficiency and applications should be within this envelope.
- Efficiency drops considerably at high pressures and high flows and specifying a pump to operate in these sections of a curve must be avoided.
- Efficiency is the most important factor in the operating costs of a pump due to energy representing about 85% of the total life cycle costs while typically the purchase price will represent only about 5%. It is therefore most important to choose the optimal efficiency pump available, even if its purchase price may be higher.

Power: The power curve is a plot of power consumed against flow. Points of note are:-

- Maximum power consumption of a pump occurs at high flows/low pressures. Usually power consumed at high pressures is lower.
- When coupling motors to pumps it is important to ensure that the power consumed at open delivery is less than the motor size or else motor failure may occur.

The following parameters affect pump performance:-

- Speed
- Impeller Diameter
- Number of impellers

Speed:

Impeller speed effects power consumed and pump performance as follows:-

- *Speed = f (power^3)*
  Doubling Speed increases power consumed by a factor of $2^3 = 8$
- *Speed = f (Pressure^2)*
  Doubling Speed increases pressure by a factor of $2^2 = 4$
- *Speed = f (flow)*
  Doubling Speed increases flow by a factor of 2

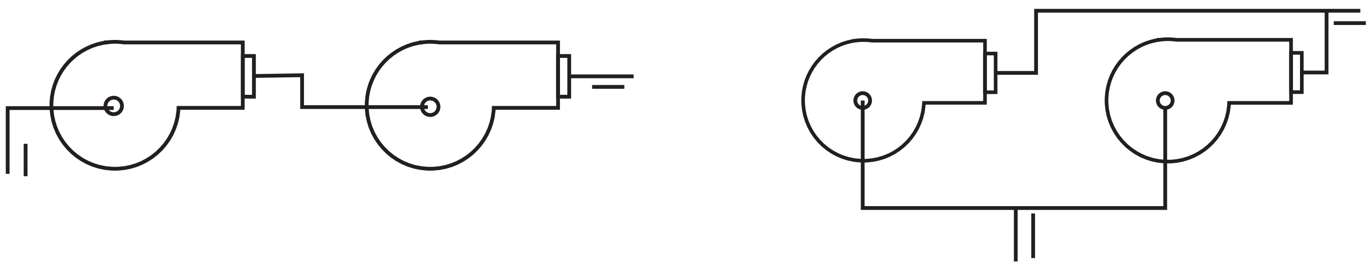
Impeller Diameter:

Impeller diameter effects pump performance in a similar way to speed.

- *Diameter = f(Power^3)*
  A 10% decrease of impeller diameter reduces power consumed by $(0.9^3\text{-}1)\text{x}100 = 27\%$
- *Diameter = f(Pressure^2)*
  A 10% decrease of impeller diameter increases pressure by $(0.9^2\text{ -}1)\text{x}100 = 19\%$
- *Diameter =f(Flow)*
  A 10% decrease of impeller diameter reduces flow by (0.9-1)x100 = 10%

Number of Impellers:

- Adding impellers in series increases pressure though has no effect on flow. This is the effect of a multistage pump.
- Adding impellers in parallel increases flow though has no effect on pressure. This is the effect of two pumps connected in parallel.



Series Connected (Multistage)

Parallel Connected (Two Pumps)

DIAGRAM 9- Impeller Configurations

3.2 Pump Shaft Horse Power

Pump Shaft Horse Power can be calculated from the formula:-

$$HP = \frac{Q \text{ x } H}{275\text{x}}$$

Where Q = flow in m^3/hr, H = Head in , η = Pump Efficiency

Section B

Pump Electrical Control

Most pumps are powered by electric motors and a correct electrical installation is essential to ensure effective operation of the pump.

1. MOTOR STARTING

The type of motor starter depends upon the type of motor being installed.

Small Single Phase Motors
Most small single-phase pumps are designed to operate without a remote starter and can be connected directly to the mains via an appropriate fuse or MCB. These pumps have built in thermal overload protection, which stops the motor in the event of an electrical or mechanical overload.

Large Single Phase Motors
Large single phase motors, usually greater than 1.5HP usually do not have built in motor protection and a Direct-on-Line starter should be used. If in doubt consult the pump supplier.

Small Three Phase Motors
Three phase motors for centrifugal surface pumps up to 7.5HP (5.5kW) need a Direct-on-Line starter with appropriate overload relay. Details are given in table 7.1.

Large Three Phase Motors
Three phase motors from 7.5kW to 30kW are usually specified with a Star Delta starter with appropriate overload relay. Details are given in table 6.

Borehole Pumps
Due to the particular design of a borehole pump motor manufacturers recommended the use of Direct-on-Line starters for all motor sizes up to 25kW and Auto-Transformer or suitable alternatives for motors above that size. Star Delta starters are not recommended.

2. MOTOR PROTECTION

Current overload can be caused by electrical or mechanical overloads in the motor or non-standard electrical supply voltages. All motor starters provide protection against current overload, the protection level being determined by the overload relay setting. It is very important to ensure that the overload relay fitted to the starter is correctly rated and set, these being determined by the full load current of the motor (see table 4). The correct overload setting is 5% above the full load motor current for DOL starters and 60% of the full load current for Star-Delta starters.

Irrespective of whether a starter is fitted or not, all pump installations must be provided with a switched coarse current protective device (either a fuse or MCB) which should be rated approximately 50% above the full load motor current.

For more sophisticated or high cost installations additional protection is often necessary and protective relays for sensing over and under supply voltage, phase asymmetry and phase failure are often provided. These units are installed as a supplement to the motor starter. Also available are electronic controllers which as well as providing a normal starting facility (usually DOL), also provide integrated current, voltage and run dry protection. It is important to discuss options with the pump supplier so the best motor protection accessories are specified.

3. PUMP CONTROLS

3.1 Level Control

Level controllers can be used to start and stop pumps either at high level or low level. A conventional installation is shown below.

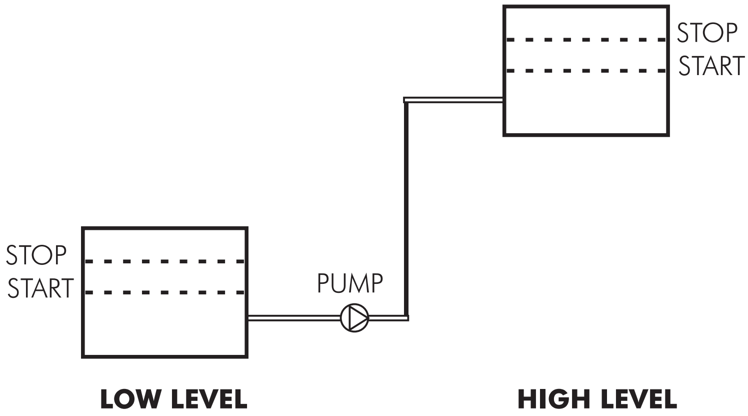


DIAGRAM 10 - Typical Pump Control Installation

Low level control is provided for pump protection to stop the pump in the event that the supply reservoir empties.

High level control is provided to stop and start the pump according to demand at the delivery reservoir.

Three types of level controllers are popularly used:-

Float Switch: This is the simplest device and operates via a float activating a lever which makes and breaks the electrical circuit. High and low level switching is adjusted by stops on a string. The advantage of these devices is their low cost, though they tend to be the least reliable of the options available.

Saddle Switch: The paddle switch is suspended above water level and makes and breaks the electrical circuit by changing from the vertical to the horizontal position. The device is reliable, economic and simple to install, though is restricted to fairly small level differentials.

Electrode Control: This is an electric device operated by means of suspended electrodes. Though the most expensive option, it is easy to install in difficult sites and provides precise level control.

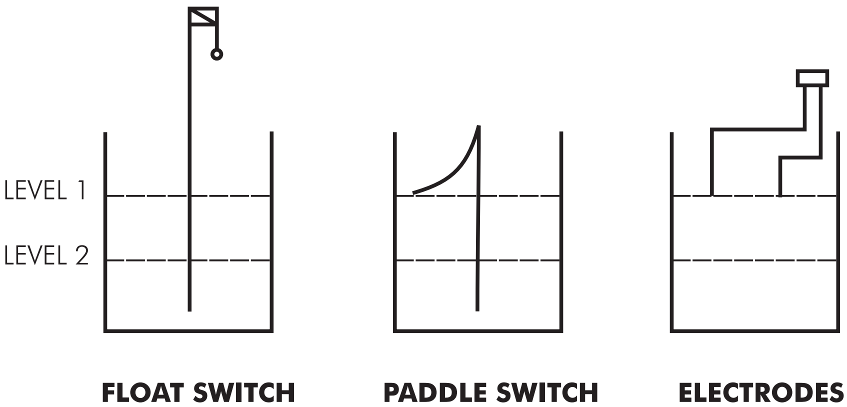


DIAGRAM 11 - Types of Level Controllers

Level controllers are generally operated by making or breaking the control circuit on a relay (often incorporated into the motor starter), which starts and stops the pump motor. For small pumps switches can be installed directly onto the pump's electrical supply, though care should be taken to make necessary connections on the neutral line to prevent switch damage.

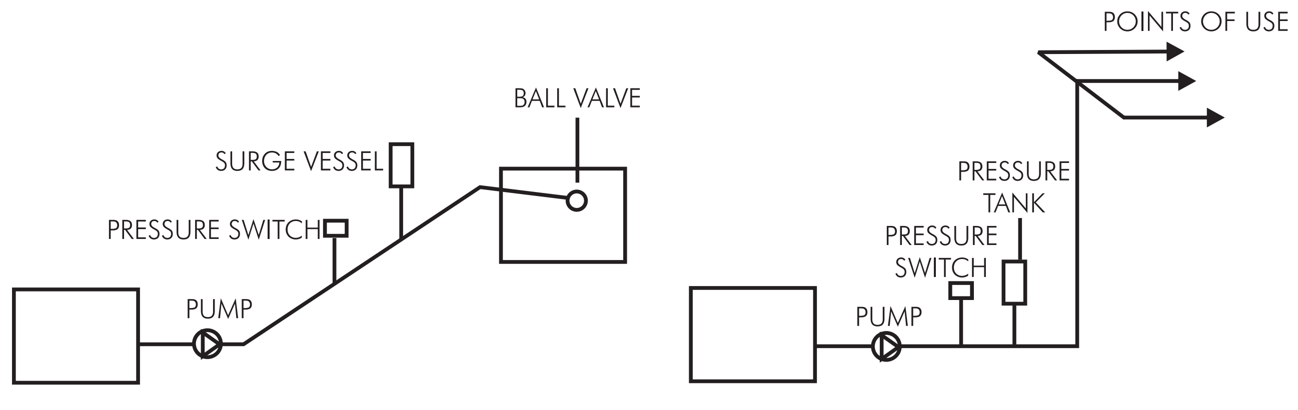
3.2 Pressure Control

Pressure switch devices are used for two functions:-

Pressure Control: To start and stop a pump instead of a level controller. Such installations are necessary when the pump is some distance from the delivery point and cabling would be expensive. Pressure control requires an appropriately rated pressure switch wired through the pump starter to start and stop the pump at preset pressures. Pump cycling is avoided by using a time delay on the starter and a small surge vessel.

Pressure Supply: To control the operation of one or more pumps depending upon site demand. For larger systems a pressure switch is used to switch the pump. Pump cycling is controlled by a larger air vessel and a time delay relay should not be fitted. For smaller systems specialized integrated control devices are available including the 'Presscontrol' and 'Hydrascan' units which switch off a low flows and switch on at low pressures.

Systems design and vessel sizing should be referred to a pump specialist.



PRESSURE CONTROL **PRESSURE SUPPLY**

DIAGRAM 12 - Types of Pressure Control Installations

3.3 Electronic Controllers

Multi function electronic controllers are the modern and most effective form of pump control which offer the benefits of much simplified installation and a wide variety of control features. Various types are available as follows:

Presscontrol Activates pump starting when line pressure drops to a pre-set of level 1.5Bar and stops in a low flow condition, which also provides protection against dry running when there is no water in the suction.

Easypress Offers similar control features to the Presscontrol, though in addition includes auto restart in the run dry condition when water returns and adjustable cut-in pressures. The units include a built-in pressure gauge.

Brio Activates pump starting when line pressure drops to a set, though adjustable line pressure and stops on adjustable pressure so the stop pressure is not the closed head of the pump. The unit also self-adjusts to pressure drops resulting from system water seepage reducing pump cycling frequency.

Torrium The most sophisticated controller available that features an adjustable start pressure, pump stopping on low flow, an intelligent processor that adjusts pump cycling to system conditions and also protects against high running current and low incoming power supply voltage.

Variable Speed Drives Controls pump output to a fixed adjustable line pressure by varying the pump motor speed. Controllers also provide protection against running dry and non standard incoming power supply voltage.

4. ELECTRICAL INSTALLATION

Correct electrical installation for all pumps is essential to ensure adequate safety and operational efficiency. The following must be considered.

Control Panels A properly specified control panel is vital to the long life and efficient operation of all pumps with various options being available, Apart from ensuring that

Cable Size: The appropriate sized cables must be used to avoid excessive voltage drops over the cable length. Voltage drops should be less than 5% from the power source to the pump, this being calculated by use of the voltage drop figures shown in table 5.

Voltage Drop = L x A x Vd
Where L = Cable Length (m)
A = Pump Operating Current (Amps)
Vd = Voltage Drop Amp/m for the cable size selected

Earthing: All installations must be correctly earthed either to the mains or to a separate earth rod installed adjacent to the control panel. Earthing has very important safety implications and a qualified electrician must be consulted on this aspect of an installation.

Wiring: Use only professional panels correctly wired to the laid down electrical standards. Inadequately wired control panels can be very dangerous and also lead to pump problems caused by bad connections.

Section C

Conversion Factors

PRESSURE
1 pound per square inch (PSI)
= 0.103 m head of water
= 2.31 feet head of water
= 0.068 Bar
1m head of water
= 3.28 feet head of water
= 1.42 pound per sq inch
= 0.097 Bar
1 Bar
= 9.8 m head of water
= 32.8 feet head of water
= 14.7 pounds per square inch

FLOW
1m^3/hr
= 16.7 litres/min
= 220 imperial gallons/hr
= 3.7 imperial gallons/min
= 277 U.S gallons/hr
= 4.6 U.S gallons per min
Imperial gallons/hr
= 1.2 U.S gallons/hr
= 4.5 litres/hr
= 0.075 litres/min

VOLUME
1 imperial gallon
= 4.545 litres
= 0.00455 cubic metre
= 1.2 U.S gallons
= 0.16 cubic feet
= 10 lbs water
1 Litre
= 0.22 imperial gallons
= 0.18 U.S gallons
1 Cubic Meter
= 20 imperial gallons
= 264 U.S gallons
= 2200 pounds water
= 35.31 cubic feet

WEIGHT
1 tonne
=1000 kgs
=2200 lbs
1 ton
= 1020 kgs
= 2240 lbs
= 20 cwt
1 Kg
= 2.2 lbs
= 35.3 ozs
= 1000 gms
1 lbs
= 160 ozs
= 454 gms
= 0.454kgs

DISTANCE
1 meter
= 3.28 ft
= 39.4 ins
= 100 cms
1 foot
=30.5 cms
1 km
= 1000 m
= 0.621 miles
1 mile
= 1.61 kms
= 5280 ft

SQUARE MEASURE
1 acre
= 4840 sq yrds
= 0.405 hectares
1 hectare
= 10,000 sq m
= 2.47 acres

TEMPERATURE
Water boils at 100^{o}C or 212^{o}F
Water freezes at 0^{o1}C or 32^{o}F
Centigrade = (F-32) x $^5/_9$
Fahrenheit = (Cx$^9/_5$) + 32

POWER
1 H.P
= 746 watts
= 33,000 ft. lbs per min
= 550 ft. lbs per second

CIRCLE FORMULAE
Circumference = π D
Area = $\pi D^2 \times {}^1/_4$
Surface area of a sphere = πD^2
Volume of cylinder = $\pi D^2 H \times {}^{1/4}$
Volume of a sphere = $^1/_6 \times \pi D^3$
Volume of a cone = $^1/_3\, \pi D^2 H \times {}^{1/4}$
D = diameter
H = height
π = 3.14

TABLE 1: PVC AND GI FRICTION LOSS TABLES

HEAD LOSS IN METRES PER 100m FOR DIFFERENT CLASSES OF PVCAND GI PIPES																										
Flow (m^3/hr)	3/4"			1"			1 1/4"			1 1/2"				2"				2 1/2"				3"				
	PVC		GI	PVC		GI	PVC		GI	PVC			GI		PVC		GI		PVC		GI	PVC				GI
1	D	E		D	E		D	E		C	D	E		C	D	E		C	D	E		B	C	D	E	
1.5	2.4	3.2	8.0			1.9			1.5																	
2	5.0	6.8	17.8	1.6	2.2	4.2			2.6																	
2.5	8.6	11	31.9	2.8	3.8	7.5	1.3	1.8	3.9				1.5													
3	12.9	17.4	49.8	4.2	5.7	11.6	2.0	2.7	5.7				2.3													
3.5	19.0	25.8	71.7	6.2	8.4	17.7	2.7	3.7	8.0	1.2	1.4	1.9	3.3													
4				8.5	11.6	25.2	3.5	4.7	10.3	1.5	1.8	2.4	4.3				1.0									
5				10.8	14.8	32.7	4.9	6.7	15.5	2.2	2.6	3.5	6.3				1.5									
6				15.5	21.3	50.5	6.9	9.3	21.7	3.1	3.6	4.9	9.0	1.0	1.2	1.6	2.1									
7				21.6	29.6	72.7	9.2	12.5	29.3	4.1	4.7	6.5	12.3	1.4	1.6	2.2	2.9									
8				28.8	41.8	98.9	11.5	15.6	38.8	5.1	5.9	8.1	15.6	1.7	2.0	2.7	3.7				1.2					
9							14.4	19.6	49.1	6.4	7.5	10.2	20.0	2.1	2.5	3.4	4.7				1.6					
10							17.5	23.8	60.7	7.8	9.0	12.4	24.6	2.6	3.0	4.1	5.8				1.9					
12								33.3	87.4	10.8	12.6	17.3	35.3	3.6	4.2	5.8	8.4	1.2	1.4	1.9	2.7					1.1
14										14.3	13.9	22.9	48.3	4.8	5.6	7.6	11.5	1.6	1.8	2.5	3.7					1.5
16										18.3	25.9	29.3	63.0	6.1	7.2	9.8	16.2	2.0	2.3	3.2	5.0					2.0
18														7.6	8.9	14.4	20.9	2.5	2.9	4.0	6.3	1.0	1.0	1.3	1.8	2.5
20														9.2	10.8	18.7	25.6	3.0	3.5	4.9	7.6	1.2	1.4	1.6	2.2	3.1
					2"				21/2″				3"					4"					6"			
					PVC			GI	PVC			GI	PVC				GI	PVC				GI	PVC			GI
					C	D	E		C	D	E		B	C	D	E		B	C	D	E		B	C	D	
20					9.2	10.8	18.7	25.6	3.0	3.5	4.9	7.6	1.2	1.4	1.6	2.2	3.1									
25					13.9	16.2	28.7	37.3	4.5	5.3	7.4	12.0	1.8	2.1	2.4	3.3	4.8					1.1				
30									6.4	7.5	10.4	17.2	2.5	2.9	3.4	4.7	6.9					1.7				
35									8.5	9.9	13.8	23.2	3.4	3.8	4.5	6.2	9.3	1.0	1.1	1.3	1.8	2.3				
40									10.9	12.5	17.7	30.3	4.3	4.9	5.8	8.0	2.2	1.2	1.4	1.7	2.3	2.9				
45									13.6	16.3	22.0	38.2	5.4	6.1	7.2	9.9	15.4	1.5	1.8	2.1	2.9	3.7				
50														7.5	9.2	12.0	19.0	1.9	2.2	2.5	3.5	4.6				
60														10.7	13.1	17.2	27.6	2.7	3.1	3.6	5.0	6.5				
70														14.3	17.8	23.0	37.3	3.6	4.1	4.8	6.7	8.8				1.2
80														17.8	23.3	28.8	48.7	4.5	5.2	6.1	8.4	11.5				1.5
90																		5.6	6.5	7.6	10.9	14.6				1.9
100																		6.8	7.9	9.2	13.5	18.0	1.0	1.2	1.4	2.4
120																		9.5	11.0	13.6	19.5	25.9	1.4	1.7	1.9	3.4
140																							1.9	2.2	2.6	4.7
160																							2.4	2.8	3.3	6.3
180																							3.0	3.5	4.1	7.9
200																							3.6	4.2	5.0	9.5
225																							4.5	5.3	6.2	11.4
250																							5.5	6.4	7.8	15.0

TABLE 2: GI PIPE SPECIFICATIONS

NOMINAL BORE (inch)	OUTSIDE DIAMETER (mm)	WALL THICKNESS (mm)			WEIGHTS (kgs per metre)			MAXIMUM WORKING PRESSURES (m)		
		CLASS A	CLASS B	CLASS C	CLASS A	CLASS B	CLASS C	CLASS A	CLASS B	CLASS C
$\frac{1}{2}$	21.4	2.0	2.6	3.3	1.0	1.2	1.5	100	200	250
$\frac{3}{4}$	27.0	2.3	2.9	3.7	1.4	1.8	2.1	100	200	250
1	34.1	2.6	3.3	4.1	2.0	2.5	3.0	100	200	250
$1\frac{1}{4}$	42.9	2.6	3.7	4.5	2.6	3.5	4.2	85	175	200
$1\frac{1}{2}$	48.4	2.9	4.1	4.9	3.3	4.5		85	175	200
2	60.3	2.9	4.1	4.9	4.2	5.7	6.7	70	140	175
$2\frac{1}{2}$	76.2	3.3	4.5	5.4	5.9	8.0	9.5	70	140	175
3	88.9	3.3	4.5	5.4	7.0	9.5	11.2	70	140	175
4	114.3	3.7	4.5	5.4	10.2	12.3	14.7	55	100	140
5	139.7		4.5	5.4		15.3	18.2		100	140
6	165.1		4.5	5.4		18.3	21.8		85	100

TABLE 3: PVC PIPE SPECIFICATIONS

NOMINAL DIAMETRE (mm)	OUTSIDE DIAMETRE (mm)	WALL THICKNESS (mm)				PER 6 METRE EFFECTIVE LENGTH				IMPERIAL SIZE (inch)
		CLASS B	CLASS C	CLASS D	CLASS E	CLASS B	CLASS C	CLASS D	CLASS E	
D25	25.2			1.6	1.8				1.2	$\frac{3}{4}$
D32	32.0		1.6	1.9	2.35			1.6	1.9	1
D40	40.2		1.8	2.4	2.85		1.9	2.5	3.0	$1\frac{1}{4}$
D50	50.2	1.6	2.2	2.9	3.5	2.1	3.0	3.8	4.6	$1\frac{1}{2}$
D63	63.2	1.9	2.8	3.6	4.45	3.3	4.7	6.1	7.4	2
D75	75.2	2.2	3.3	4.2	5.15	4.6	6.7	8.5	10.2	$2\frac{1}{2}$
D90	90.2	2.7	3.9	5.1	6.2	6.7	9.6	12.2	14.8	3
D110	110.2	3.3	4.8	6.1	7.55	10.0	14.3	18.4	22.2	4
D160	160.3	4.7	6.8	8.9	10.95	29.5	42.2	54.9	66.4	6
D200	200.3	5.2	7.6	10.0	12.3	37.6	53.7	69.1	83.9	7

NOTE: Maximum Pressure Ratings

Class B = 6 Bar   Class D = 12 Bar
Class C = 9 Bar   Class E = 15 Bar

TABLE 4: MOTOR CURRENT RATINGS, OVERLOAD & CIRCUIT BREAKER SIZES

MOTOR SIZE		SINGLE PHASE 240V			THREE PHASE 415V				
						Direct On Line		Star/Delta	
kw	HP	Max Full Load Current (A)	O/L Rating (A)	C/B Rating (A)	Max Full Load Current (A)	O/L (A)	C/B (A)	O/L (A)	C/B (A)
0.37	0.5	3.5	2.5 - 4	6					
0.75	1.0	6.0	5.5 - 8	10					
1.10	1.5	8.8	7 - 10	15	2.7	2.5 - 4	6		
1.50	2.0	11.0	9 - 13	16	3.6	2.5 - 4	6		
2.20	3.0	17.0	12 - 18	25	5.3	4 - 6	10		
3.70	5.0				8.4	7 - 10	16	4 - 6	16
5.50	7.5				12.0	9 - 13	16	5.5 - 8	16
7.50	10.0				16.0	12 - 18	20	7 - 10	20
11.20	15.0				23.0	17 - 25	32	9 - 13	32
15.00	20.0				29.0	23 - 32	40	12 - 18	40
18.50	25.0				36.0	28 - 36	50	17 - 25	50
22.00	30.0				42.0	37 - 50	63	17 - 25	63
30.00	40.0				56.0	48 - 65	80	23 - 32	80
37.00	50.0				69.0	55 - 70	100	30 - 40	100
45.00	60.0				82.0	80 - 125	125	37 - 50	125
55.00	75.0				100.0	80 - 125	175	48 - 65	175
75.00	100.0				134.0	100 - 160	225	63 - 80	225

NOTE: O/L = Overload C/B = Circuit Breaker

TABLE 5: CABLE CURRENT CAPACITY AND VOLTAGE DROP DATA

CONDUCTOR OR SIZE (mm^2)	MULTICORE AMOURED PVC INSULATED CABLE (PVC -SWA)				TWIN AND MULTICORE PVC INSULATED CABLE			
	Two core cable Single Phase supply		Three or four core cable Three phase supply		Two core cable Single phase supply		Three or four core cable	
	Max current capacity (A)	Voltage drop per amp per metre (mv)	Max current capacity (A)	Voltage drop per amp per metre (mv)	Max current capacity (A)	Voltage drop per amp per metre (mv)	Max current capacity (A)	Voltage drop per amp per metre (mV)
1.5	22	29.00	19	25.0	19.5	29.00	17.5	25.0
2.5	31	18.00	26	15.0	27	18.00	24	15.0
4.0	41	11.00	35	9.5	36	11.00	32	9.5
6.0	53	7.30	45	6.4	46	7.30	41	6.4
10.0	72	4.40	62	3.8	63	4.40	57	3.8
16.0	97	2.80	83	2.4	85	2.80	76	2.4
25.0	128	1.75	110	1.5	112	1.75	96	1.5
35.0	157	1.25	135	1.1	138	1.25	119	1.1
50.0	190	0.94	163	0.81	168	0.94	144	0.81

TABLE 6: BOREHOLE DROP CABLE SIZING

	MOTOR SIZE		FULL LOAD CURRENT	MIN. CABLE SIZE	CABLE DIMENSION							
					1.5mm²	2.5mm²	4mm²	6mm²	10mm²	16mm²	25mm²	35mm²
	kW	HP	A	mm²	MAXIMUM LENGTHS FOR SUBMERSIBLE BOREHOLE CABLE (m)							
ONE PHASE	0.37	0.5	3.5	1.5	130							
	0.55	0.75	5.0	1.5	90	150						
	0.75	1.0	6.7	1.5	70	110	180					
	1.1	1.5	7.2	1.5	60	100	170	260				
	1.5	2.0	10.6	1.5		70	120	180	310			
	2.25	3.0	15.8	2.5		50	80	120	200			
THREE PHASE	1.1	1.5	3.1	1.5	300	510						
	1.5	2.0	3.9	1.5	240	400						
	2.25	3.0	5.5	1.5	170	280	460					
	3.75	5.0	8.7	1.5	100	180	290	440				
	5.63	7.5	13	2.5		120	190	290	510			
	7.5	10	17.2	2.5			140	220	380			
	11.3	15	24	4			100	160	270	430		
	15	20	32	4			80	120	200	320	500	
	18.8	25.2	40	6				90	160	260	400	
	22	30	46	10					140	220	350	490
	26	35	57.5	10					110	180	280	390
	30	40	66.5	16						150	240	340
	37	50	80	16						130	200	280

TABLE 7: ARMOURED CABLE SPECIFICATIONS

NOMINAL CONDUCTOR AREA (mm^2)	THREE CORE - ARMOURED - 600/1000 VOLT CABLE Cable having stranded copper conductors				FOUR CORE - ARMOURED - 600/1000 VOLT CABLES Cable having stranded copper conductors			
	MAXIMUM RESISTANCE PER 1000m OF:		OVERALL DIAMETER (mm)	WEIGHT PER METRE (kg)	MAXIMUM RESISTANCE PER 1000m OF:		OVERALL DIAMETER (mm)	WEIGHT PER METRE (kg)
	Conductor (ohm)	Armour (ohm)			Conductor (ohm)	Armour (ohm)		
1.5	12.10	10.2	12.3	0.3	12.10	9.5	13.0	0.7
2.5	7.28	8.8	13.6	0.4	7.28	7.9	14.5	0.7
4.0	4.61	7.0	15.8	0.6	4.61	4.6	17.8	0.8
6.0	3.08	4.6	18.0	0.7	3.08	4.1	19.2	0.9
10.0	1.83	3.7	21.2	1.0	1.83	3.4	22.8	1.3
16.0	1.15	3.8	20.6	1.1	1.15	2.6	23.9	1.5
25.0	0.727	2.4	25.0	1.7	0.727	2.1	27.8	2.1
35.0	0.524	2.1	27.3	2.1	0.524	1.9	30.5	2.6
50.0	0.387	1.9	30.5	2.6	0.387	1.3	35.4	3.4